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Bulloch et al.

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(54) **APPARATUS, SYSTEM, AND METHOD FOR INTRA-ORAL DISTRACTION**

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A61B 17/60 (2006.01)

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USPC **606/105**; 606/57

(58) **Field of Classification Search**
USPC 606/55, 57, 58, 90, 71, 105, 282, 606/320
See application file for complete search history.

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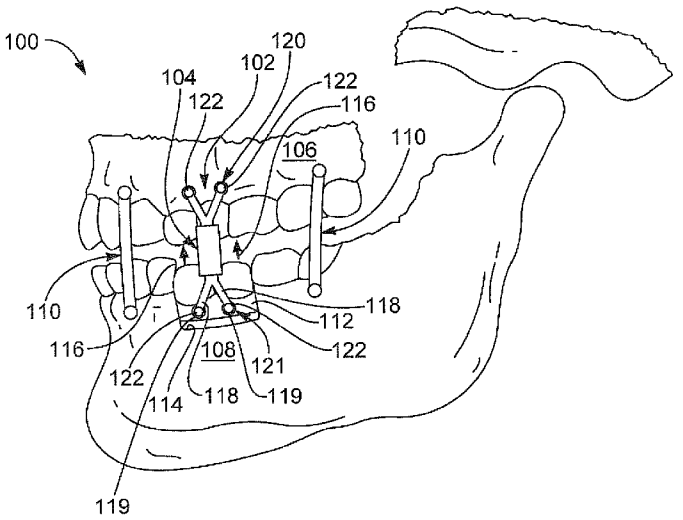
(57) **ABSTRACT**

According to one representative embodiment, a method for distracting a segment of bone from a source bone includes providing a bone distractor that has a first end portion and a second end portion movable relative to each other. The method further includes coupling the first end portion to the segment of bone and coupling the second end portion to an anchor bone opposing the source bone. Additionally, the method includes actuating the bone distractor to move the first and second end portions closer to each other and pull the segment of bone toward the anchor bone. The method can also include fixing the source bone relative to the anchor bone. Further, the method can include positioning the bone distractor to the sides of the source bone, anchor bone, and a gingival layer covering the bones.

12 Claims, 5 Drawing Sheets



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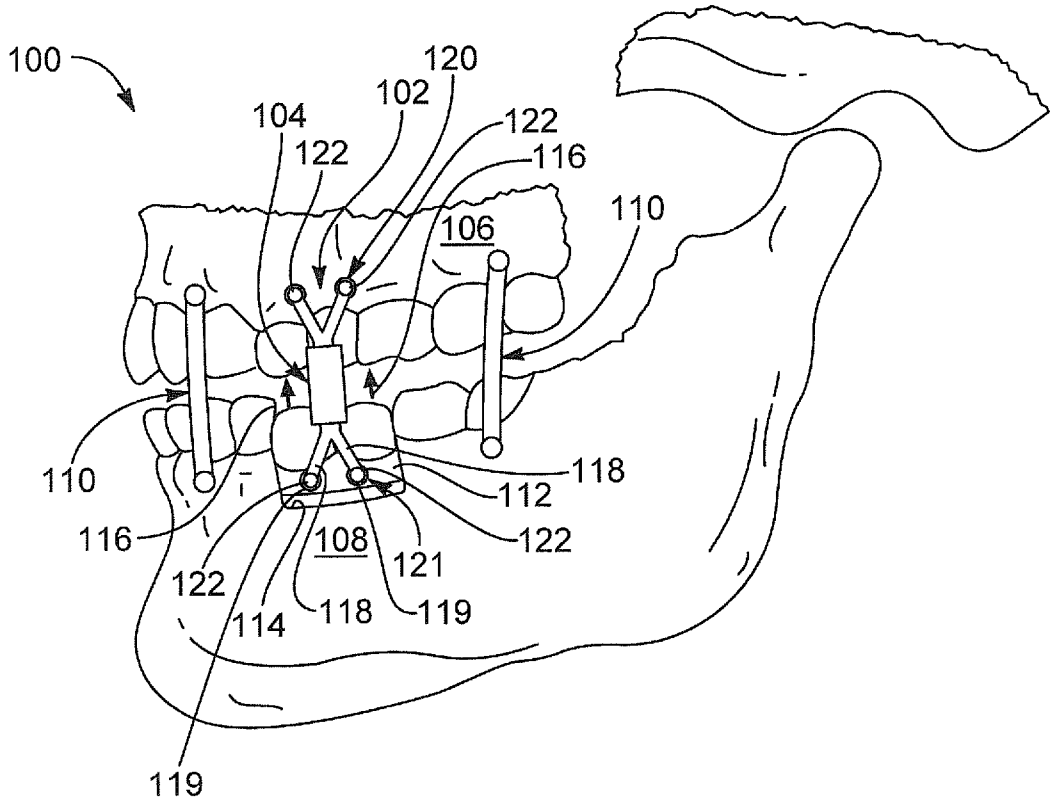
100
120
102
104
122
122
116
110
106
110
118
112
116
122
108
121
122
114
118
119
119

FIG. 1

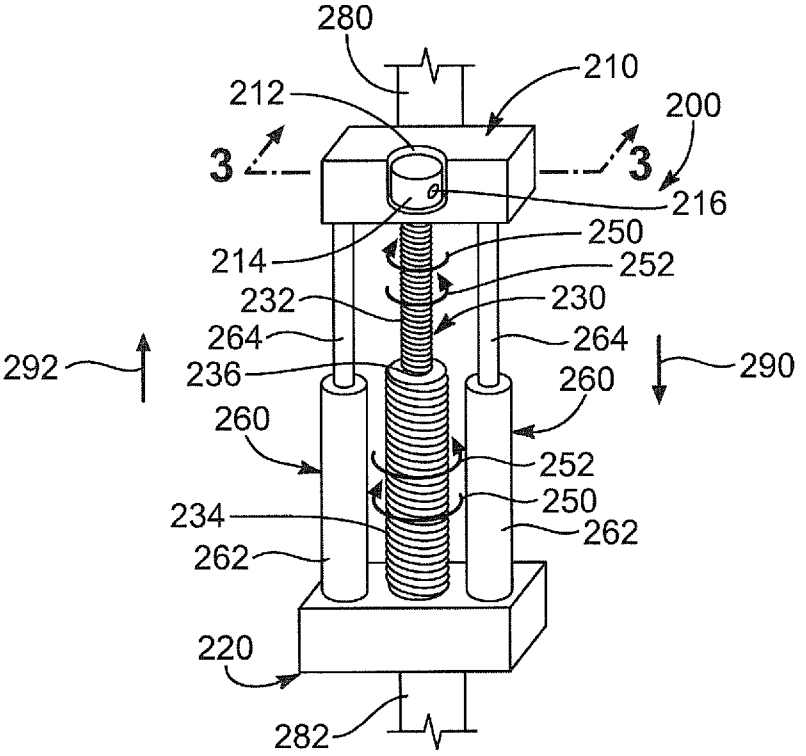
280
210
212
200
3
3
216
214
250
252
232
230
264
264
292
236
290
260
260
252
234
250
262
262
220
282

FIG. 2

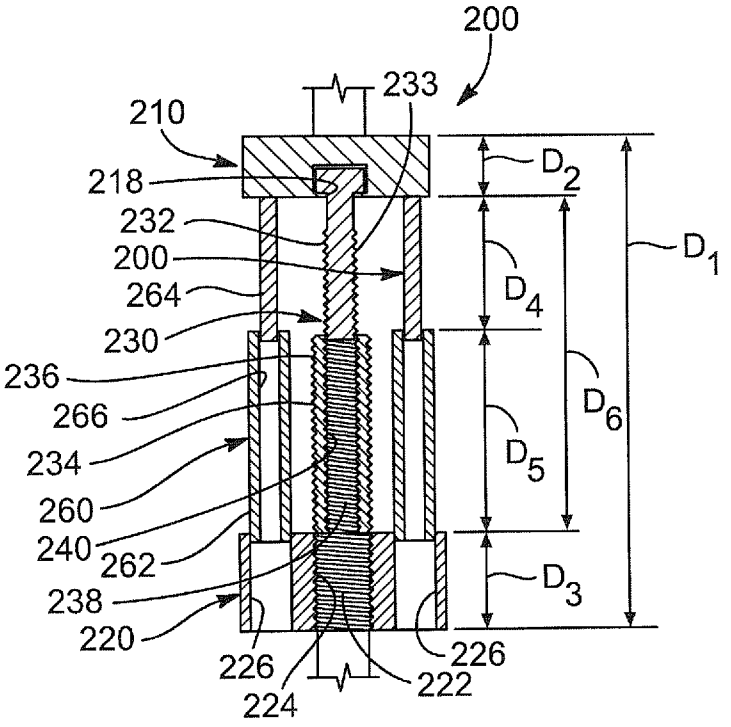
200
233
210
218
232
200
264
230
236
266
234
260
240
262
238
220
226
224
222
226
D2
D1
D4
D6
D5
D3

FIG. 3

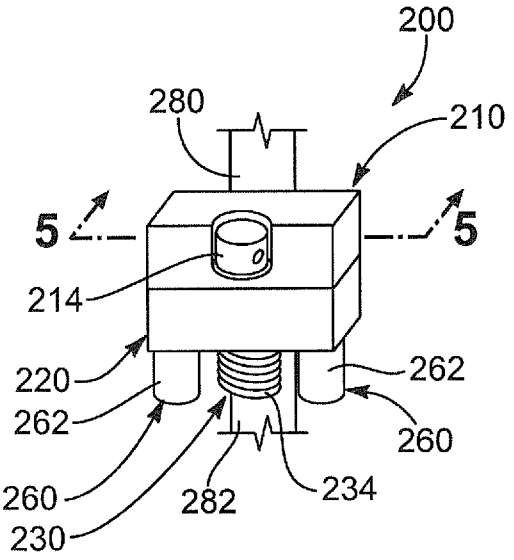
200
280
210
5
5
214
220
262
262
260
260
230
282
234

FIG. 4

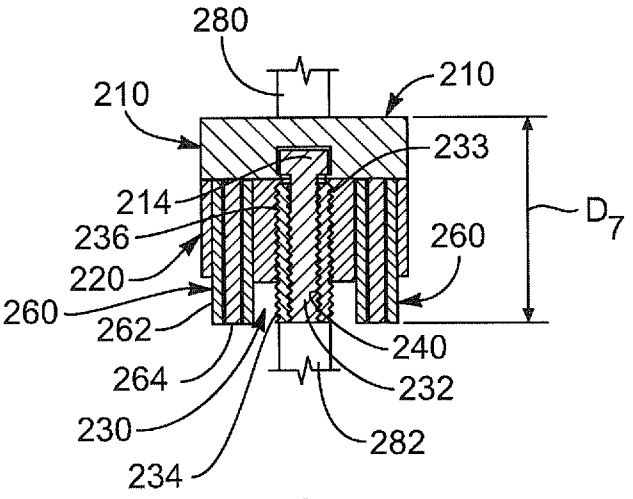
280
210
210
233
214
236
220
260
260
262
240
264
232
230
282
234
D7

FIG. 5

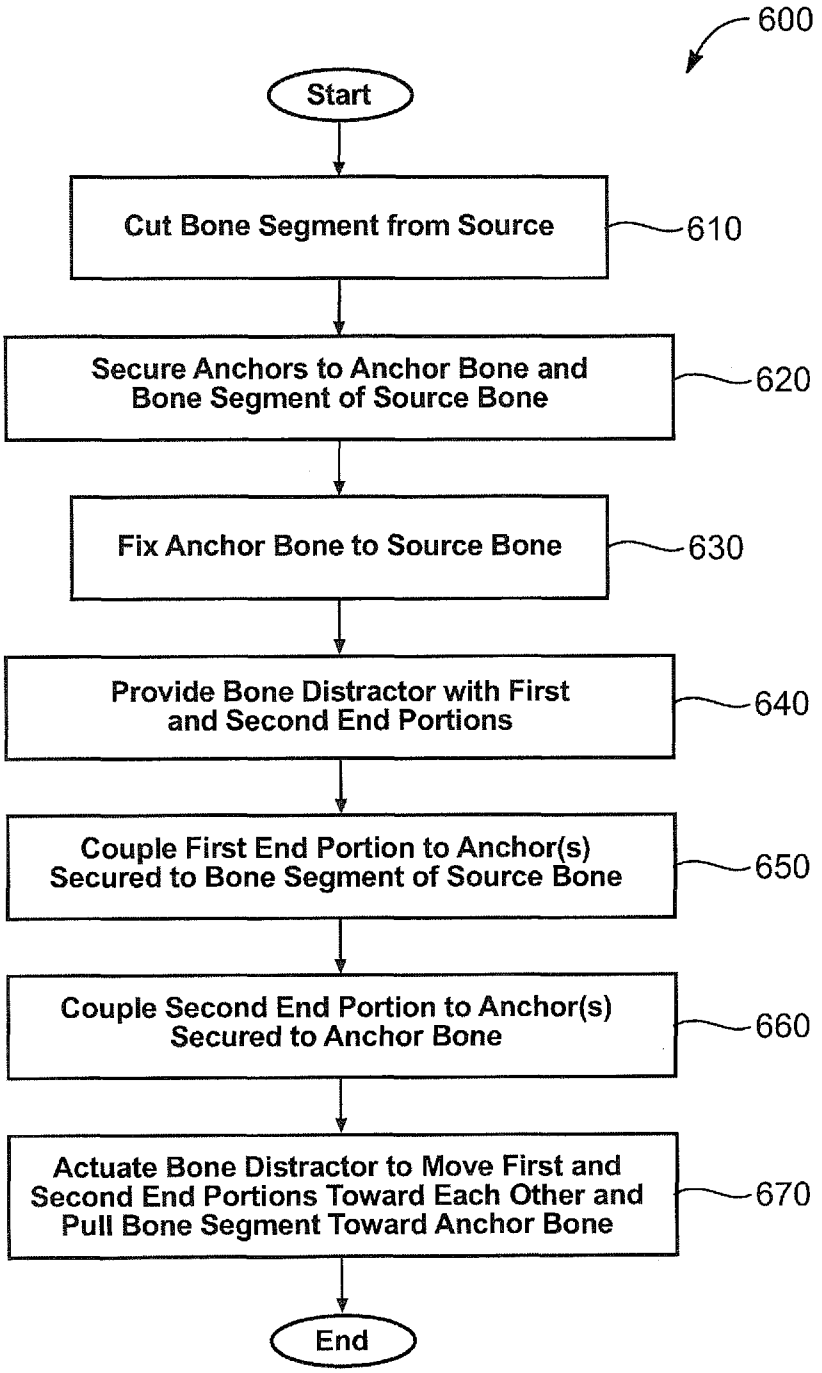
600
Start
Cut Bone Segment from Source
610
Secure Anchors to Anchor Bone and Bone Segment of Source Bone
620
Fix Anchor Bone to Source Bone
630
Provide Bone Distractor with First and Second End Portions
640
Couple First End Portion to Anchor(s) Secured to Bone Segment of Source Bone
650
Couple Second End Portion to Anchor(s) Secured to Anchor Bone
660
Actuate Bone Distractor to Move First and Second End Portions Toward Each Other and Pull Bone Segment Toward Anchor Bone
670
End

FIG. 6

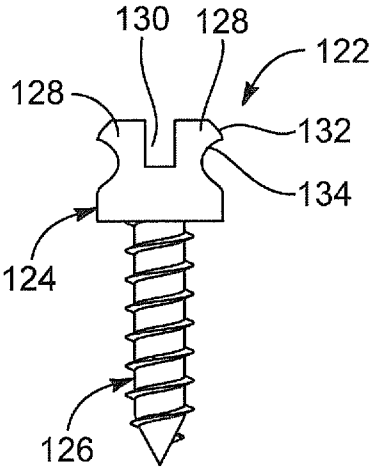
130
128
122
128
132
134
124
126

FIG. 7A

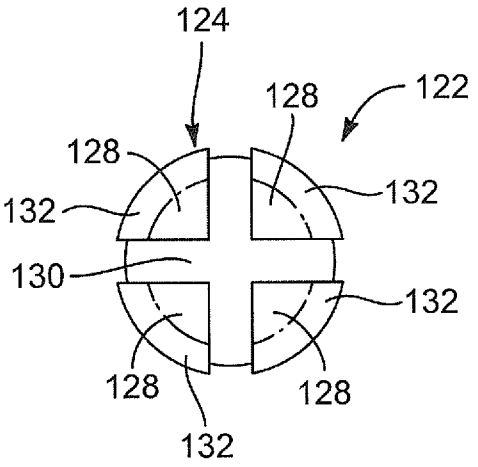
124
128
122
128
132
132
130
132
128
128
132

FIG. 7B

APPARATUS, SYSTEM, AND METHOD FOR INTRA-ORAL DISTRACTION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional application of U.S. patent application Ser. No. 12/257,054, filed Oct. 23, 2008, which is incorporated herein by reference.

FIELD

This invention relates to bone distraction and more particularly to intra-oral bone distraction.

BACKGROUND

Distraction osteogenesis is the process of lengthening bone tissue by cutting a bone segment from a source bone and gradually moving the bone segment away from the bone. The ends of the bone segment and source bone along the cut line are spaced apart to allow the formation of new bone tissue within the gap between the bone segment and source bone. As the bone segment is gradually moved away from the source bone, new bone tissue continues to grow between the bone segment and source bone until a desired length of the source bone, e.g., a desired increase in the length of the source bone, is reached. After the desired bone length is reached, the new bone tissue is allowed to heal until the tissue reaches an appropriate density the same as or similar to the source bone.

Traditionally, distraction osteogenesis techniques were limited to the field of orthopedics. Recently, however, distraction osteogenesis techniques have been applied to correct deformities of the jaw. Such jaw bone distraction techniques typically involve cutting away a bone segment from a source jaw bone, e.g., one of the maxilla or mandible jaw bones, securing a distraction device to the bone segment and the source jaw bone, and adjusting the distraction device to push the bone segment away from the source jaw bone.

Conventional jaw bone distraction techniques and devices suffer from several drawbacks. For example, pushing a bone segment away from the source jaw bone reduces the force vector control of the moving segment. Additionally, current bone distraction devices that push the bone segment away from the source jaw bone are typically attached or embedded within a patient's tissue, which can limit access and adjustment of the distractor and increase the risk of infection. Further, current bone distraction devices have a single threaded rod that facilitates adjusting of the devices. Such a configuration results in a distraction device with a limited action to length ratio, e.g., range of motion of the distraction device to overall minimum length ratio. In other words, the distance the distractor is able to push the bone segment is relatively small compared to the minimum overall length of the distractor itself. This results in a large device with a small range of motion.

SUMMARY

The subject matter of the present application has been developed in response to the present state of the art, and in particular, in response to the problems and needs in the art that have not yet been fully solved by currently available bone distraction apparatus, systems, and methods. Accordingly, the subject matter of the present application has been developed to provide a bone distractor and associated apparatus, systems, and methods that overcome at least some shortcomings of the prior art.

According to one embodiment, a bone distraction system for distracting a portion of bone from a source bone includes a first anchor portion couplable to an anchor bone and a second anchor portion couplable to a distractable bone segment of the source bone. The system includes a distractor coupling the first anchor portion and the second anchor portion. The overall length of the distractor is decreasable to pull the distractable bone segment toward the anchor bone for distracting the bone segment.

In certain implementations, the distractor includes a first end portion couplable to the first anchor portion, a second end portion couplable to the second anchor portion, and a telescoping portion extendable between the first and second end portions. The telescoping portion can be rotatable relative to the first and second end portions such that rotation of the telescoping portion reduces a distance between the first and second portions. In specific instances, the telescoping portion comprises a first threaded rod and a second threaded rod, the first and second threaded rods being rotatable relative to each other. The distractor can also include at least one support member adjacent the telescoping portion and extendable between the first and second end portions.

In some implementations, the ratio of a maximum range of linear motion of the distractor to a minimum overall length of the distractor is greater than about 11:15. In yet some implementations, the overall length of the distractor is adjustable between a maximum length and a minimum length. The ratio of the maximum length to the minimum length can be at least about 21:9.

The anchor bone can be one of the maxilla jaw bone and mandible jaw bone and the source bone can be the other of the maxilla jaw bone and mandible jaw bone. According to some implementations, when the first anchor portion is coupled to the anchor bone and the second anchor portion is coupled to the distractable bone segment, the distractor is external relative to the anchor bone, bone segment, and any tissue covering the anchor bone and bone segment.

In certain implementations, at least one of the first and second anchor portions of the system include a generally Y-shape having at least two spaced-apart eyelets each configured to receive a respective anchor. Further, the first and second anchor portions can each include at least one anchor that has a threaded portion and a head portion. The threaded portion can be embeddable within one of the anchor bone and bone segment and the head portion can include a plurality of flexible members

According to yet another embodiment, a distractor for distracting a bone segment cut from a first jaw bone includes a first end portion couplable to one of the bone segment and a second jaw bone spaced apart from the first jaw bone. The distractor also includes a second end portion couplable to the other of the bone segment and the second jaw bone. Further, the distractor includes at least one telescoping member extending between the first and second end portions. The telescoping member is actuatable to decrease the distance between the first and second end portions and increase the distance between the bone segment and the source bone.

According to some implementations, the at least one telescoping member includes a first telescoping member having a first threaded portion threadably engageable with a second threaded portion. The first threaded portion can include a first rod having a series of external threads and a bore having a series of internal threads. The second threaded portion can include a second rod having a series of external threads. The

external threads of the second rod can be threadably engageable with the internal threads of the first rod. In certain instances, one of the first and second end portions includes a bore having a series of internal threads such that the external threads of the second rod are threadably engageable with the internal threads of the bore of the one of the first and second end portions.

In some implementations, the at least one telescoping member includes a second telescoping member that includes a first non-threaded portion slidably engageable with a second non-threaded portion. In yet some implementations, the at least one telescoping member includes a third telescoping member that has a third non-threaded portion slidably engageable with a fourth non-threaded portion. In such implementations, the first telescoping member is positioned between the second and third telescoping members.

According to one implementation, the distractor is adjustable between a minimum overall length and a maximum overall length. The ratio of a maximum distance between the first and second end portions to the minimum overall length can be greater than about 14:9.

In another embodiment, a method for distracting a segment of bone from a source bone includes providing a bone distractor that has a first end portion and a second end portion movable relative to each other. The method further includes coupling the first end portion to the segment of bone and coupling the second end portion to an anchor bone opposing the source bone. Additionally, the method includes actuating the bone distractor to move the first and second end portions closer to each other and pull the segment of bone toward the anchor bone. The method can also include fixing the source bone relative to the anchor bone. Further, the method can include positioning the bone distractor to the sides of the source bone, anchor bone, and a gingival layer covering the bones.

In some implementations of the method, the bone distractor includes a threaded telescoping portion extending between the first and second end portions. In such implementations, actuating the bone distractor includes rotating the threaded telescoping portion relative to the first and second end portions. According to some implementations, at least one of the first and second end portions includes internal threads. The threaded telescoping portion can include a first member that has external threads and internal threads and a second member having external threads. In such implementations, rotating the threaded telescoping portion includes at least one of threadably engaging the internal threads of the first member with the external threads of the second member and threadably engaging the external threads of the first member with the internal threads of the at least one of the first and second end portions.

According to some implementations, coupling the first end portion to the segment of bone includes coupling the first end portion to at least one anchor embedded within the segment of bone and extending from a side of the segment of bone. Further, coupling the second end portion to the anchor bone can include coupling the second end portion to at least one anchor embedded within the anchor bone and extending from a side of anchor bone.

Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the subject matter of the present disclosure should be or are in any single embodiment. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present disclosure. Thus, discussion of the features and advantages, and similar language, throughout this specification may, but do not necessarily, refer to the same embodiment.

Furthermore, the described features, advantages, and characteristics of the subject matter of the present disclosure may be combined in any suitable manner in one or more embodiments. One skilled in the relevant art will recognize that the subject matter may be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments. These features and advantages will become more fully apparent from the following description and appended claims, or may be learned by the practice of the subject matter as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the advantages of the subject matter may be more readily understood, a more particular description of the subject matter briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the subject matter and are not therefore to be considered to be limiting of its scope, the subject matter will be described and explained with additional specificity and detail through the use of the drawings, in which:

FIG. **1** is a side elevation view of a bone distraction system according to one representative embodiment;

FIG. **2** is a perspective view of a bone distractor according to one representative embodiment shown in a fully open position;

FIG. **3** is a cross-sectional side view of the bone distractor of FIG. **2** taken along the lines **3-3** of FIG. **2**;

FIG. **4** is a perspective view of the bone distractor of FIG. **2** shown in a fully closed position;

FIG. **5** is a cross-sectional side view of the bone distractor of FIG. **4** taken along the lines **5-5** of FIG. **4**;

FIG. **6** is a schematic diagram of a method for distracting a bone segment using a bone distractor;

FIG. **7**A is a side elevation view of an anchor of a bone distraction system according to one embodiment; and

FIG. **7**B is a top plan view of the anchor of FIG. **7**A.

DETAILED DESCRIPTION

Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment," "in an embodiment," and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

Additionally, instances in this specification where one element is "coupled" to another element can include direct and indirect coupling. Direct coupling can be defined as one element coupled to and in some contact with another element. Indirect coupling can be defined as coupling between two elements not in direct contact with each other, but having one or more additional elements between the coupled elements. Further, as used herein, securing one element to another element can include direct securing and indirect securing. Additionally, as used herein, "adjacent" does not necessarily

denote contact. For example, one element can be adjacent another element without being in contact with that element.

Furthermore, the details, including the features, structures, or characteristics, of the subject matter described herein may be combined in any suitable manner in one or more embodiments. One skilled in the relevant art will recognize, however, that the subject matter may be practiced without one or more of the specific details, or with other methods, components, materials, and so forth. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the disclosed subject matter.

Generally, described herein are embodiments of a bone distractor and associated apparatus, systems, and methods for lengthening a bone. In one embodiment, the distractor includes a threaded telescoping portion that is adjustable to pull a bone segment away from a source bone. The telescoping portion can include a first threaded rod insertable into and threadably engageable with a second threaded rod. The second threaded rod can be threadably engageable with an end portion or guide element. The threaded telescoping portion facilitates an increased action to length ratio compared to conventional distraction devices. Moreover, because the distractor pulls the bone segment, rather than pushes it, the control of the force vectors on the bone segment is increased compared to conventional distraction devices. Additionally, because the distractor pulls the bone segment, the distractor does not need to be secured or embedded within the patient's bone tissue as with conventional bone pulling distraction devices.

One representative embodiment of a bone distraction system **100** is shown in FIG. **1**. The bone distraction system **100** includes a distractor system **102** and at least one jaw fixator **110**. In the illustrated embodiment, the bone distraction system **100** includes at least two jaw fixators **110**. Each fixator **110** is secured to the jaw bones, i.e., the maxilla or upper jaw bone **106** and the mandible or lower jaw bone **108**, at opposing ends. When secured to the jaw bones **106**, **108**, the fixators **110** hold the jaw in place to prevent the jaw from opening or otherwise preventing movement of the jaw bones **106**, **108** relative to each other. The fixators **110** can be any of various maxilla-mandibular fixation devices commonly used in the art and any of various techniques known in the art can be used to secure the fixation devices to the jaw bones.

As will be described in more detail below, after the jaw bones **106**, **108** are fixed relative to each other using the fixators **110**, the bone distractor system **102** is secured to the jaw bones. The bone distractor system **102** includes a bone distractor **104** coupled to the jaw bones **106**, **108** via a pair of connectors **120**, **121**. As shown, the connector **120** is secured to the maxilla jaw bone **106** by a pair of anchors **122** embedded in the maxilla jaw bone and the connector **121** is secured to a bone segment **112** of the mandible jaw bone **108** by a pair of anchors **122**. Each anchor **122** is embedded into the respective bone or bone segment using any of various techniques known in the art, e.g., screwing the anchors **122** into the bone or bone segment. The connectors **120**, **121** are fastened, or otherwise secured, to the bone distractor **104** and include a pair of arms **118** diverging away from the bone distractor **104**. An eyelet **119** is positioned proximate an end of each arm **118**. The eyelets **119** fit over a respective anchor **122** to secure the connectors **120**, **121**, and thus the bone distractor **104**, to the jaw bone **106** and bone segment **112**. Although the connectors **120**, **121** illustrated in FIG. **1** have a generally "Y" shape with two eyelets **119**, in other embodiments, the connectors can have any of various shapes and sizes and have any of a number of eyelets or anchor attachments.

The bone distractor **104** is configured to pull the bone segment **112** away from a source bone toward an anchor bone. The source bone is defined as the bone from which a bone segment to be moved is cut and the anchor bone is defined as the bone toward which the bone segment is moved. In the illustrated embodiment, the source bone is the mandible jaw bone **108** and the anchor bone is the maxilla jaw bone **106**. In other embodiments, however, the source bone can be the maxilla jaw bone **106** and the anchor bone can be the mandible jaw bone **108**. Similarly, in non-oral applications, the source and anchor bones can be any other bones in the body in relative proximity to each other. As shown, the bone distractor **104** pulls the bone segment **112** away from the mandible jaw bone **108** and toward the maxilla jaw bone **106** in a direction indicated by arrows **116**. The bone segment **112** is cut from the mandible jaw bone **108** along cut line **114**. As the bone segment **112** moves away from the mandible jaw bone **108** at a predetermined rate or over predetermined increments, new bone tissue fills in the gap between the bone segment **112** and mandible jaw bone to effectively lengthen the mandible jaw bone.

Referring to FIG. **2**, a bone distractor **200** is shown coupled to opposing connectors **280**, **282**. The bone distractor **200** can be used in place of bone distractor **104** and the connectors **280**, **282** can be similar to connectors **120**, **121**. The bone distractor **200** includes first and second end portions **210**, **220**, respectively. As shown, the bone distractor **200** includes a threaded telescoping member **230** and two non-threaded telescoping members **260** extending between the first and second end portions **210**, **220**. Generally, the threaded telescoping member **230** is actuatable to adjust the overall distance D_6 between the first and second end portions **210**, **220**.

The first end portion **210**, or top end portion as shown, includes a recess **212** sized and shaped to receive an adjustment knob **214**. The recess **212** is formed in the first end portion **210** and configured to allow the adjustment knob **214** to be at least partially embedded within the first end portion. Desirably, the vertical heights of the first and second end portions **210**, **212** are limited to reduce obstruction with portions of the client's mouth and/or other orthodontic appliances. Therefore, in certain implementations, the adjustment knob **214** is embedded within the first end portion **210** as shown such that the knob does not protrude from the top of the first end portion **210**. Although less preferable, in some embodiments, the adjustment knob **212** can be secured to an outer surface of the first end portion **210** and protrude away from the first end portion. The adjustment knob **212** includes a tool engager **216**, such as a specifically-shaped recess or aperture, for receiving an adjustment tool (not shown).

The adjustment knob **214** couples the threaded telescoping member **230** to the first end portion **210**. More specifically, a first threaded rod **232** of the telescoping member **230** extends through an aperture **218** formed in the first end portion **210** that opens to the recess **212** (see FIG. **3**). The first threaded rod **232** connects to the adjustment knob **214** such that rotation of the adjustment knob **214** correspondingly rotates the first threaded rod **232**.

Referring to FIG. **3**, the second end portion **220** includes a first aperture, e.g., first bore **222**, extending through the second end portion. The first bore **222** is sized to receive a second threaded rod **234** of the threaded telescoping member **230**. The diameter of the first bore **222** is just larger than the outer diameter of the second threaded rod **234**. Moreover, a series of internal threads **224** are formed on an internal surface of the first bore **222**. The pitch and diameter of the internal threads **224** correspond with the pitch and diameter of external threads **236** of the second threaded rod **234** such that the

second threaded rod **234** is insertable into and threadably engageable with the first bore **222**.

Referring again to FIG. **3**, the second end portion **220** also includes a pair of second apertures, e.g., second bores **226**, extending through the second end portion. Each second bore **226** is sized to receive a second rod **262** of a respective one of the non-threaded telescoping members **260**. Generally, the outer diameters of the second rods **262** are approximately the same as the diameters of the second bores **226**.

Although the illustrated first and second end portions **210**, **220** are shown having a generally rectangular block shape, in other embodiments, the end portions can have any of various shapes and sizes conducive to the particular application for which the distractor **200** is being used.

The threaded telescoping member **230** includes the first threaded rod **232** in telescoping engagement with the second threaded rod **234**. The first threaded rod **232** includes a series of external threads **233** extending along a substantial length of the first threaded rod. In certain implementations, the external threads **233** extend along the entire length of the first threaded rod **232**. The second threaded rod **234** includes the external threads **236** as discussed above and internal threads **240** formed in an internal surface of a bore **238** extending through the second threaded rod **234**. The thread pitch and diameter of the internal threads **240** of the second threaded rod **234** correspond to the thread pitch and diameter of the external threads **233** of the first threaded rod **232** such that the first threaded rod **232** is insertable into and threadably engageable with the bore **238** of the second threaded rod. The first threaded rod **232** and the second threaded rod **234** are telescopingly engageable because the first threaded rod can be inserted into the second threaded rod such that the second threaded rod overlaps the first threaded rod.

Moreover, while in telescoping engagement, as the first and second threaded rods **232**, **234** are rotated relative to each other, the threaded engagement between the external and internal threads **233**, **240**, respectively, causes the threaded rods to move coaxially relative to each other in directions indicated by directional arrows **290**, **292** (see FIG. **2**). In other words, as the first threaded rod **232** is rotated relative to the second threaded rod **234**, the first threaded rod **232** moves linearly along the bore **238** of the second threaded rod and the second threaded rod moves linearly along the outside of the first threaded rod. The overall effect of rotating the first threaded rod **232** and second threaded rod **234** relative to each other is an adjustment of the overall length of the bone distractor **200**, the distance D_4 between the first end portion **210** and the second threaded rod, and the distance D_6 between the first and second end portions **210**, **220** (see FIG. **3**). More specifically, for threads **233**, **240** with a left-handed thread pattern, rotation of the first threaded rod **232** in a clockwise direction **250** (see FIG. **2**) relative to the second threaded rod **234** increases the distances D_4 and D_6. Similarly, rotation of the first threaded rod **232** in a counterclockwise direction **252** relative to the second threaded rod **234** decreases the distances D_4 and D_6.

Concurrently with or separately from the first threaded rod **232** rotating relative to the second threaded rod **234**, the second threaded rod **234** is rotatable relative to the second end portion **220**. More specifically, the external threads **236** of the second threaded rod **220** are threadably engageable with the internal threads **224** of the first bore **222** such that rotation of the second threaded rod **232** causes the second threaded rod to move linearly along the first bore **222** in one of directions **290**, **292** depending on the direction of rotation. The overall effect of rotating the second threaded rod **234** is an adjustment of the overall length of the bone distractor **200**, the distance D_5 between the first threaded rod **232** and the second end portion **220**, and the distance D_6 between the first and second end portions **210**, **220** (see FIG. **3**). More specifically, for threads **224**, **236** with a left-handed thread pattern, rotation of the second threaded rod **234** in a clockwise direction **250** (see FIG. **2**) relative to the second end portion **220** increases the distances D_5 and D_6. Similarly, rotation of the second threaded rod **234** in a counterclockwise direction **252** relative to the second end portion **220** decreases the distances D_5 and D_6. Although the illustrated threads have a left-handed thread pattern, in other embodiments, the threads can have a right-handed thread pattern such that rotating the threaded rods in the clockwise direction **250** decreases the distances D_4, D_5, D_6, and rotating the threaded rods in the counterclockwise direction **252** increases the distances D_4, D_5, D_6.

The bone distractor **200** is adjustable between a maximum overall length D_1 (see FIG. **3**) and a minimum overall length D_7 (see FIG. **5**). As shown in FIGS. **2** and **3**, when the distractor **200** is at the maximum overall length D_1, the distractor is in a fully open position. Similarly, as shown in FIGS. **4** and **5**, when the distractor **200** is at the minimum overall length D_7, the distractor is in a fully closed position. Further, the distractor **200** is adjustable to any of various positions intermediate the fully open and closed positions.

In certain implementations, the overall length of the distractor is at the maximum overall length D_1, i.e., in the fully open position, when the distance D_4 is approximately equal to the total length of the first threaded rod **232** and the distance D_5 is approximately equal to the total length of the second threaded rod **234**. Accordingly, the first threaded rod **232** can be rotated in the clockwise direction **250** until the distance D_4 is approximately equal to the total length of the first threaded rod and the second threaded rod **234** can be rotated in the clockwise direction until the distance D_5 is approximately equal to the total length of the second threaded rod.

The minimum overall length D_1 of the distractor **200** is the overall length of the distractor when the distances D_4, D_5 are each equal to approximately zero, e.g., when the first and second end portions **210**, **220** are in contact with each other. The distractor **200** can be adjusted to the minimum overall length D_7, i.e., into the fully closed position, by rotating the first and second threaded rods **232**, **234** in the counterclockwise direction **252** until the distances D_4, D_5 are each equal to approximately zero. As shown in FIG. **5**, in certain embodiments, when the distractor **200** is in the fully closed position, the first and second threaded rods **232**, **234** (with the first threaded rod being within the bore **238** of the second threaded rod) extend from the second end portion **220** in a direction away from the first end portion **210**.

The maximum distance D_6, e.g., the maximum distance D_4 plus the maximum distance D_5, corresponds with a maximum action capability or maximum range of motion of the bone distractor **200**. As defined herein, the maximum range of motion is the maximum distance a distractor can move a bone segment in a bone distraction process. Typically, bone distractors are rated according to an action to length ratio, i.e., a ratio of the maximum range of motion of the distractor to the minimum overall length of the distractor. For some conventional bone distractors, a typical action to length ratio is no more than about 11:15. Generally, because of the threaded telescoping member **230**, e.g., the threaded rod within a threaded rod configuration, the action to length ratio of the bone distractor of the present application is higher than conventional distractors. According to various embodiments of the bone distractor of the present application, e.g., bone distractor **200**, the action to length ratio is between about 11:15 and about 14:9. In one particular embodiment, the action to

length ratio of the bone distractor **200** is about 14:9. The higher action to length ratios of the distractors described herein allow for smaller and more compact distractors, while providing greater ranges of motion, than conventional distractors. These characteristics facilitate easier placement and flexibility in the distraction osteogenesis process, as well as to reduce the discomfort often associated with large and cumbersome bone distraction devices.

Referring back to FIG. **2**, the bone distractor **200** includes the non-threaded telescoping members **260** for providing structural support and rigidity to the distractor. Each non-threaded telescoping member **260** includes a first rod **264** in telescoping engagement with the second rod **262**. The first rod **264** is secured to the first end portion **210** and extends at least partially within a bore **266** formed in the second rod **262**. Likewise, the second rod **262** extends at least partially within a respective one of the second bores **226** formed in the second end portion **220**. Although the distractor **200** includes two non-threaded telescoping members **260** in the illustrated embodiment, in other embodiments, the distractor can have one or more than two non-threaded telescoping members as desired.

The non-threaded telescoping members **260** actuate concurrently with actuation of the threaded telescoping member **230**. In other words, as the first and second threaded rods **232**, **234** are rotated to increase or decrease the distance D_6 between the first and second end portions **210**, **220**, the first rod **264** correspondingly moves along the bore **266** and/or the second rod **262** correspondingly moves along a respective second bore **226**. For example, when the distractor **200** is moved into the fully closed position (see FIG. **5**), the first rod **264** moves in the direction **290** relative to the second rod **262** until the entire first rod is within the second rod. As shown in FIG. **5**, in certain instances, when the distractor **200** is in the fully closed position, the first and second rods **264**, **262** of the respective non-threaded telescoping members **260** protrude from the second end portion **220** away from the first end portion **210**.

In some embodiments, the distractor **200** includes a stop for preventing disengagement between the first threaded rod **232** and second threaded rod **234**. In other words, the stop prevents the distractor **200** from actuating beyond the fully open position. In one embodiment, the stop includes one or more pins engageable with corresponding grooves that extend along the inner surface of the bore **266**. The grooves can terminate just prior to the opening of the bore **266**. As the distractor **200** is opened, the pins slide along the grooves until they contact an end of the grooves, which prevents further movement of the pins and movement of the first end portion **210** away from the second end portion **220**. In other embodiments, the stop can be any of various stop mechanisms known in the art.

Referring to FIG. **6**, a method **600** is shown for distracting a bone segment using a bone distractor, e.g., distractor **200**, according to one representative embodiment. The method includes cutting **610** a bone segment from a source bone, e.g. the mandible jaw bone **108**. The bone segment represents a width of bone to be lengthened. Cutting **610** the bone segment can include any of various methods known in the art. For example, in the illustrated embodiment, cutting **610** the bone segment **112** includes cutting the mandible jaw bone **108** along the cut line **114**. The bone segment **112** can be cut with minimal degloving of the overlying soft tissue and minimal disruption of the blood supply. Any open overlying soft tissue is closed after cutting **610** the bone segment **112**. After cutting **610** the bone segment **112**, in one implementation, the bone segment **112** is stabilized in its original location relative to the source bone for a desired period of time, e.g., one week, to allow growth of elastic fibers between the source bone and bone segment.

Before, or after, cutting **610** the bone segment, anchors, e.g., anchors **122**, are secured **620** to the bone segment and the anchor bone, e.g., maxilla jaw bone **106**. For example, in the illustrated embodiment, two anchors **122** are secured to the bone segment **112** and two anchors **122** are secured to the maxilla jaw bone **106**. In certain implementations, the anchors **122** are screw-like elements and securing **620** the anchors includes screwing the anchors into the bone. In some situations, a pilot hole can be drilled into to bone to facilitate proper embedment and orientation of the anchor **122** in the bone. In one implementation, after securing **620** the anchors in place, the method **600** includes fixing, e.g., wiring, **630** the anchor bone to the source bone using any of various fixation techniques and devices known in the art. In one implementation, jaw fixators **110** are used to wire **630** the anchor bone to the source bone. Wiring the anchor bone to the source bone can provide vertical stability of the jaw bones.

The method **600** further includes providing **640** a bone distractor with first and second end portions. In certain embodiments, the bone distractor can be the bone distractor **200** shown in FIGS. **2-4** and the first and second end portions can be first and second end portions **210**, **220**. The first end portion is coupled **650** to the anchors **122** secured to the bone segment. Similarly, the second end portion is coupled **660** to the anchors **122** secured to the anchor bone. Coupling **650**, **660** of the first and second end portions to the anchors **122** can be facilitated by a pair of connectors each coupled to a respective end portions and each having anchor engaging portions, e.g., eyelets **119**. The first and second end portions are coupled **660** to the anchors by positioning the eyelets **119** of the connectors over or about the head portions.

As shown in FIGS. **7**A and **7**B, in some implementations, the anchors **122** each include a head portion **124** and a threaded portion **126**. The threaded portion **126** is embedded, e.g., screwed, into the patient's gingival and bone tissue such that the head portion **124** is exposed on the outer surface of the patient's tissue. The head portion **124** includes a plurality of resiliently movable tabs **128** to facilitate removable attachment of the eyelets **119** to the anchors. The tabs **128** each have a beveled portion **132** to facilitate ease in coupling the eyelets **119** to the anchors **122** and a concave portion **134** opposing the beveled portion **132** to assist in retaining the eyelets **119** on the head portion **124**. Generally, the concave portions **134** make it harder to remove the eyelets **119** than to attach the eyelets. In an unflexed state, the outer surfaces of the tabs **128** define a circumference having a diameter slightly larger than an inner diameter of the eyelets **119**.

The tabs **128** are configured to flex inwardly toward each other as an eyelet **119** is positioned about and slid onto the head portion **124** toward the threaded portion **126**. As the eyelet **119** slides past the tabs, **128**, the tabs rebound back to their original shape thus retaining the eyelet on the section of the head portion **124** intermediate the tabs and the threaded portion **126**. The eyelet **119** is removed from the head portion **124** by pulling or sliding the eyelet away from the threaded portion **126** and against the tabs **128** with sufficient force to overcome the bias of the tabs and flex the tabs inwardly such that the eyelet can be slid off of the head portion **124**. The anchor **122** includes a tool engagement portion **130** defined between the tabs **128**. A fastening tool, such as a flathead or Phillips screw driver, can engage the tool engagement portion **130** to secure the anchor **122** to the patient's jaw.

Preferably, as shown in the illustrated embodiments, the bone distractor is intra-oral. In other words, the bone distrac-

tor shown is not embedded within, inserted into, or otherwise positioned within the bone, gingival, or other tissue of the jaw. For example, the distractor **200** is a para-jaw distractor positioned to the side of the jaw, as opposed to being embedded within the jaw. Because the bone distractor **200** is to the side of the jaw, the adjustment knob **214** is easily accessible to provide for easy adjustment of the distractor. Further, because the bone distractor **200** is not embedded within the jaw tissue, the risk of infection is reduced compared to bone distractors that are embedded within the jaw tissue, such as via invasive surgical procedures.

After the first and second end portions are secured **650**, **660** to the anchors **122**, the bone distractor is actuated **670** to move the first and second end portions toward each other and pull the bone segment toward the anchor bone. Referring to distractor **200**, actuating **670** the distractor **200** includes pulling the bone segment **112** towards the maxilla jaw bone **106** by rotating the adjustment knob **214** in a counterclockwise direction. The adjustment knob **214** can be rotated by inserting an adjustment tool, such as a wire or hexagonal wrench, into the tool engager **216** and applying a rotational force to the adjustment tool.

In certain embodiments, actuating **670** the distractor includes incrementing the rotation of the adjustment tool according to a predefined actuation schedule. For example, after initial coupling of the distractor **200** to the bone segment **112** and maxilla jaw bone **106**, the doctor can actuate **670** the distractor into a starting position. For example, when initially coupled to the bone segment **112** and maxilla jaw bone **106**, the distractor **200** can be in the fully open position. The doctor then actuates **670** the distractor **200** to place the distractor in some position intermediate the fully open and fully closed positions. The starting position can correspond to a predetermined initial gap between the bone segment **112** and the mandible jaw bone **108**. After setting the distractor **200** in the starting position, the doctor, the patient, or a third party intermittently rotates the adjustment knob according to the actuation schedule to move the bone segment incrementally closer to the anchor bone.

Based on the thread pattern of the threads **224**, **233**, **236**, **240**, each full rotation of the adjustment knob corresponds to a predetermined range of motion or action or the first and second end portions **210**, **220**, e.g., a predetermined decrease in the distance D_6. Accordingly, from the starting position, the predefined actuation schedule may require periodically rotating the adjustment tool a predetermined amount to pull the bone segment **112** toward the anchor bone **106** a predetermined distance. In specific implementations, each full rotation of the adjustment knob **214** corresponds to one millimeter of action or a reduction of one millimeter from the distance D_6. Therefore, in some instances, depending on the patient's particular characteristics, the predefined actuation schedule may request a quarter turn of the adjustment knob **214** every day to move the bone segment **112** a quarter of a millimeter each day. Of course the amount of rotation or action of the bone segment **112** and the frequency of the rotations can vary from patient to patient and from condition to condition.

The intermittent adjustment of the distractor **200** continues until a desired result in achieved, at which time the distractor and anchors in the anchor bone can be removed from the patient. With the distractor removed, the bone segment can be stabilized in its new location relative to the source bone using the anchors in the bone segment to allow the bone segment to heal in the new location. Once healed, the anchors can be removed from the bone segment.

The schematic flow chart diagrams herein are generally set forth as logical flow chart diagrams. As such, the depicted order and labeled steps are indicative of one embodiment of the presented method. Other steps and methods may be conceived that are equivalent in function, logic, or effect to one or more steps, or portions thereof, of the illustrated method. Additionally, the format and symbols employed are provided to explain the logical steps of the method and are understood not to limit the scope of the method. Although various arrow types and line types may be employed in the flow chart diagrams, they are understood not to limit the scope of the corresponding method. Indeed, some arrows or other connectors may be used to indicate only the logical flow of the method. For instance, an arrow may indicate a waiting or monitoring period of unspecified duration between enumerated steps of the depicted method. Additionally, the order in which a particular method occurs may or may not strictly adhere to the order of the corresponding steps shown.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A method for distracting a segment of bone from a source bone, the method comprising:

providing a bone distractor comprising a first end portion and a second end portion movable relative to each other;

coupling the first end portion directly to the segment of bone;

coupling the second end portion directly to an anchor bone opposing the source bone, the anchor bone being a naturally different bone than the source bone; and

actuating the bone distractor to move the first and second end portions closer to each other and pull the segment of bone toward the anchor bone.

2. The method of claim **1**, further comprising fixing the source bone relative to the anchor bone.

3. The method of claim **1**, wherein the bone distractor comprises a threaded telescoping portion extending between the first and second end portions, and wherein actuating the bone distractor comprises rotating the threaded telescoping portion relative to the first and second end portions.

4. The method of claim **3**, wherein:

at least one of the first and second end portions comprises internal threads;

the threaded telescoping portion comprises a first member having external threads and internal threads and a second member having external threads; and

rotating the threaded telescoping portion comprises at least one of threadably engaging the internal threads of the first member with the external threads of the second member and threadably engaging the external threads of the first member with the internal threads of the at least one of the first and second end portions.

5. The method of claim **1**, wherein:

coupling the first end portion to the segment of bone comprises coupling the first end portion to at least one anchor embedded within the segment of bone and extending from a side of the segment of bone; and

coupling the second end portion to the anchor bone comprises coupling the second end portion to at least one anchor embedded within the anchor bone and extending from a side of anchor bone.

6. The method of claim 1, further comprising positioning the bone distractor to the sides of the source bone, anchor bone, and a gingival layer covering the bones.

7. A method for distracting a bone segment of a source bone from the source bone, the method comprising:

immovably fixing the source bone relative to an anchor bone;

movably fixing the bone segment of the source bone directly to the anchor bone; and

with the source bone immovably fixed relative to the anchor bone and the bone segment movably fixed to the anchor bone, pulling the bone segment of the source bone toward the anchor bone;

wherein the anchor bone comprises one of the maxilla jaw bone and mandible jaw bone and the source bone comprises the other of the maxilla jaw bone and mandible jaw bone.

8. The method of claim 7, wherein pulling the bone segment of the source bone toward the anchor bone comprises decreasing a distance between the anchor bone and the bone segment of the source bone.

9. The method of claim 7, further comprising cutting the bone segment away from the source bone.

10. The method of claim 9, wherein cutting the bone segment comprises cutting the bone segment along a cut line, and wherein pulling the bone segment of the source bone toward the anchor bone comprises increasing a distance between the bone segment of the source bone and the cut line.

11. The method of claim 7, wherein the bone segment of the source bone is separated from the source bone along a cut line, and wherein pulling the bone segment of the source bone toward the anchor bone comprises increasing a distance between the bone segment of the source bone and the cut line.

12. A method for distracting a segment of bone from a source bone, the method comprising:

providing a bone distractor comprising a first end portion and a second end portion movable relative to each other;

coupling the first end portion to the segment of bone;

coupling the second end portion to an anchor bone opposing the source bone; and

actuating the bone distractor to move the first and second end portions closer to each other and pull the segment of bone toward the anchor bone;

wherein the bone distractor comprises a threaded telescoping portion extending between the first and second end portions, and wherein actuating the bone distractor comprises rotating the threaded telescoping portion relative to the first and second end portions; and

wherein at least one of the first and second end portions comprises internal threads, the threaded telescoping portion comprises a first member having external threads and internal threads and a second member having external threads, and rotating the threaded telescoping portion comprises at least one of threadably engaging the internal threads of the first member with the external threads of the second member and threadably engaging the external threads of the first member with the internal threads of the at least one of the first and second end portions.

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